Astrophysical Masers and their Environments
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Japanese VLBI network observations of 6.7-GHz methanol masers II. Results

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Abstract. We are using a Japanese VLBI network (JVN) for VLBI observations of 6.7-GHz methanol masers associated with massive star-forming regions. Here we present results for Cepheus A (Cep A) from observations taken on September 9, 2006. The distribution of the maser spots indicates either a spherical bubble or a disk having an inclination of several tens degree. We construct a disk model with an inclination of $\sim$70° and a radius of $\sim$700 AU. From a luminosity of 1.7×10^4 $L_\odot$ for a source observed in this region, the excitation of the maser is probably radiative.

Keywords. masers, stars: formation, HII regions, ISM: individual (Cepheus A)

1. Introduction

Methanol masers at 6.7 GHz provide a useful probe for investigating star formation associated with massive young stellar objects (YSOs). The masers often show linear structures and linear velocity gradients, and these are often interpreted as evidence for edge-on disks (e.g., Pestalozzi *et al.* 2004). However, other morphologies could also explain the maser distributions.

There are 519 known sites of 6.7 GHz methanol maser listed (Pestalozzi *et al.* 2005), while the number of sources observed with VLBI at milli-arcsecond (mas) resolution is, currently, less than 30. We have begun VLBI observations of maser sources at 6.7 GHz with a Japanese VLBI network (JVN; Doi *et al.* 2006) with five antennas, Yamaguchi 32 m, Usuda 64 m, VERA-Mizusawa, Ishigaki and Iriki 20 m.

In this paper, we describe results from observations of Cepheus A (Cep A). The observations were taken on September 9, 2006. Cep A has a CO condensation at a distance of 730 pc (Johnson 1957) and is known to have some massive star forming regions. One of these is an UC HII region, Cep A-HW 2, which is the site of the methanol maser emission. It is also known that a biconical ionized jet exists in Cep A-HW 2 from radio continuum observations (Torrelles *et al.* 1996).

2. Results and discussion

The distribution of maser spots of Cep A (Figure 1) shows an incomplete arc which could be part of a spherical bubble, or a disk with an inclination of several tens degree. We assume here that the distribution of spots traces a tilted disk because of the nearly perpendicular direction to the radio jet. We also assume that the maser spots are excited in regions of the same radiation temperature, i.e. that they are at the same distance from

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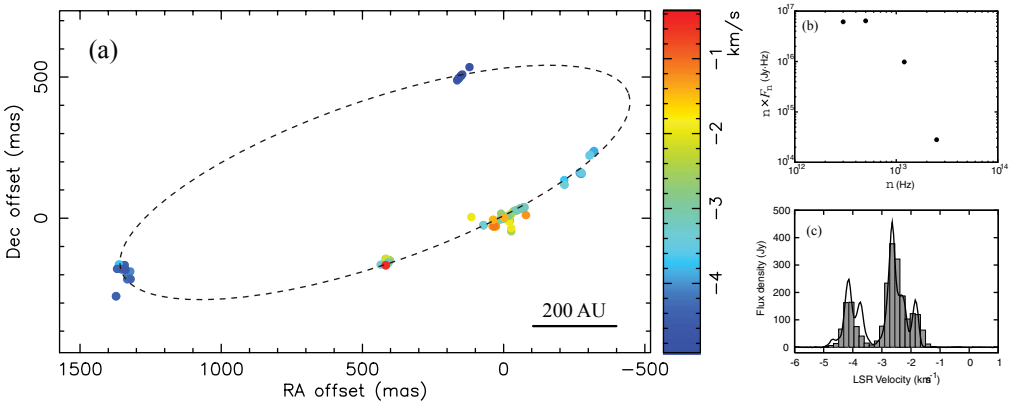

Figure 1. Cep A: (a) distribution of methanol maser at 6.7 GHz. (b) IRAS flux at each wavelength (12, 25, 60, 100 μm) versus frequency for IRAS 22543+6145. (c) The filled box shows the CLEANed component spectrum while the solid line shows the single-dish (total-power) spectrum.

an excitation source. According to this model, we have fitted the distribution with an ellipse and obtained a radius of $R \sim$700 AU with an inclination of $\sim$70°. The radiation temperature at this radius is estimated as follows. We first calculate the luminosity of the (suspected) excitation source of an IRAS point source (IRAS 22543+6145) located at Cep A-HW 2, by using formula (3) from Walsh *et al.* (1997). For a distance to Cep A of 730 pc, a luminosity of $L = 1.7{\times}10^4\ L_\odot$ is obtained. We can then derive the radiation temperature T_d with:

$$T_\mathrm{d} = (16\pi\sigma)^{-1/4} \cdot R^{-1/2} \cdot L^{1/4} \tag{2.1}$$

where σ is the Stefan-Boltzmann constant. The temperature obtained, $T_\mathrm{d} \sim$120 K, agrees well with a theoretical value >100 K (Cragg *et al.* 2002). This is consistent with a single excitation source and the methanol maser spots in Cep A distributed within a disk of diameter 1400 AU.

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